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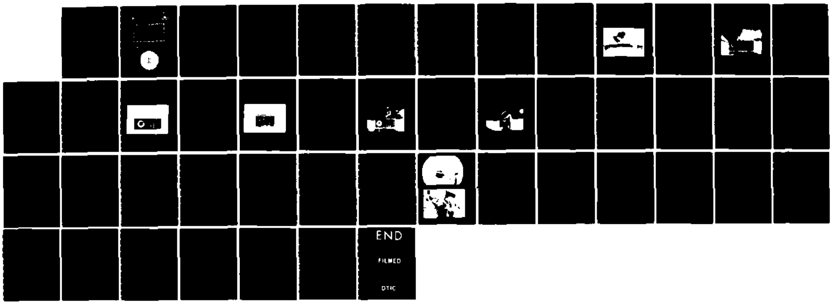

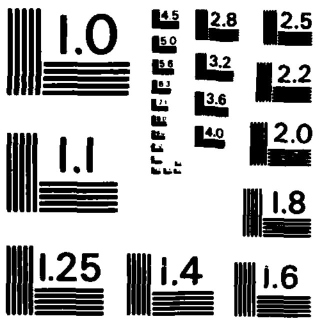

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AD-A148 692

NAVY EXPERIMENTAL DIVING UNIT

REPORT NO. 8-84

RECOMPRESSION CHAMBER COMMUNICATION SYSTEMS TEST AND EVALUATION

...RY D. PELTON
MIC...

APRIL 1984

Navy Experimental Diving Unit

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DEPARTMENT OF THE NAVY
NAVY EXPERIMENTAL DIVING UNIT
PANAMA CITY, FLORIDA 32407

IN REPLY REFER TO:

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RECOMPRESSION CHAMBER COMMUNICATION SYSTEMS TEST AND EVALUATION

JERRY D. PELTON
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APRIL 1984

Approved for public release; distribution unlimited

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Five commercially available Hardwire Communications Systems were tested at the Navy Experimental Diving Unit for use as two-wire communications systems on recompression chambers. These systems were designed to serve as the primary means of communication between outside personnel and personnel inside the chamber. The communication systems were evaluated and rated by how well they fulfilled specific critical parameters related to this application. The five systems evaluated were Helle Models 3220 and 3214, Amron Model AMCOM II 2820, EFCOM Model DAR-1000, and Atkinson Dynamics Model AD-27H-M2.

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Overall, the AMCOM II and EFCOM DAR-1000 were rated the best communicators by the system operators on human factors variables. The poorest evaluation was received by the Helle 3214, with less than satisfactory ratings received in two sub-areas and in the overall rating. The overall ranking of the systems was in agreement with the operators' confidence in each communicator. In summary, the AMRON Model AMCOM II and the EFCOM Model DAR-1000 communication systems were considered to be reliable and effective instruments of communication with occupants in U.S. Navy recompression chambers from 0 to 165 FSW. Originator-supplied keywords include; Diver phones, and MIL-STD 810C.

Table of Contents

Glossary

ABS	Acrylonitrile Butadiene Styrenes (plastic)
AC	volts, alternating current
AMP	ampere
ANU	Authorized for Navy Use
cm	centimeter
db	decibels
DC	volts, direct current
DV	diver
FSW	feet of seawater
ft.	foot (length)
Hz	Hertz (cycles per second) (frequency)
In.	inch (length)
KHz	Kilohertz
lbs.	pounds (weight)
MIL-STD	military standard
mm	millimeter
MRT	modified rhyme test
NAVMED	NAVAL MEDICAL COMMAND
NEDU	Navy Experimental Diving Unit
Ohms	Impedance (electrical resistance)
PCB	printed circuit board
@	at
#	number
%	percent
Ω	Ohms
'	feet/foot
"	inch

ABSTRACT

Five commercially available Hardwire Communications Systems were tested at the Navy Experimental Diving Unit for use as two-wire communications systems on recompression chambers. These systems were designed to serve as the primary means of communication between outside personnel and personnel inside the chamber. The communication systems were evaluated and rated by how well they fulfilled specific critical parameters related to this application. The five systems evaluated were Helle Models 3220 and 3214, Amron Model AMCOM II 2820, EFCOM Model DAR-1000, and Atkinson Dynamics Model AD-27H-M2. Overall, the AMCOM II and EFCOM DAR-1000 were rated the best communicators by the system operators on human factors variables. The poorest evaluation was received by the Helle 3214, with less than satisfactory ratings received in two sub-areas and in the overall rating. The overall ranking of the systems was in agreement with the operators' confidence in each communicator. In summary, the AMRON Model AMCOM II and the EFCOM Model DAR-1000 communication systems were considered to be reliable and effective instruments of communication with occupants in U.S. Navy recompression chambers from 0 to 165 FSW.

KEY WORDS:

Hardwire Communications
Communicators
Diver Phone
Recompression Chambers
Human Factors
MIL-STD-810C

INTRODUCTION

The purpose of this test was to evaluate the adequacy of five commercially available Hardwire Communications Systems to meet the Navy requirements for chamber use. All tests were conducted by Navy Experimental Diving Unit (NEDU) personnel at Panama City, Florida and were under the auspices of NEDU Test Plan 83-28 "Evaluation of Commercially Available Underwater Hardwire Telephone (Hardwire Diver's Communication Systems)". This report correlates the test results and presents evaluation comparisons on the HELLE Models 3220 and 3214, AMRON Model AMCOM II 2820, EFCOM Model DAR-1000, and the ATKINSON DYNAMICS Model AD-27H-M2. The evaluation presentation includes:

A. An assessment of the safety and human engineering characteristics of the communications systems as a result of bench tests and user inputs (APPENDICES B1, B2 and B3).

B. A word intelligibility assessment using the Modified Rhyme Test (MRT) which was conducted with both equipment and operators subjected to the actual conditions of expected use (sample APPENDIX A1 and A2).

C. A study of the interoperability of these communicators with existing equipment, i.e. chambers, transceivers and wiring.

DESCRIPTION OF COMMUNICATION SYSTEMS

Five Hardwire Communications Systems were tested and are pictured in Figure 1. The manufacturers' addresses and model numbers of the systems tested are shown in Table 1. Each system was purchased directly from its respective manufacturer and shipped to Panama City, Florida, where all of the testing was conducted. A brief description of each system follows.

HELLE Model 3214 Wire Diver Phone. The 3214 wire diver phone (Figure 2) is an intercom system between a surface tender and from one to three divers (in this case personnel inside the recompression chamber) at the same time or to each diver individually. Specifications for the communicator are listed in Table 2.

The system was packaged in an ABS plastic case with a flat cover of the same material. The front panels were aluminum with descriptive lettering silkscreened onto the panels, and all connections were made on the front panels. The system as tested was powered by two internal lantern type 6 VDC batteries which were each connected in series for the 12 VDC needed to power the unit. A low voltage indicator light on the front panel was set to activate when the operating voltage fell below 7 VDC. The cabinet speaker functions as both a speaker and a microphone; the speakers inside the test chamber provided the same dual function. The system was tested in the two wire mode (see Figure 3 for wiring layout).

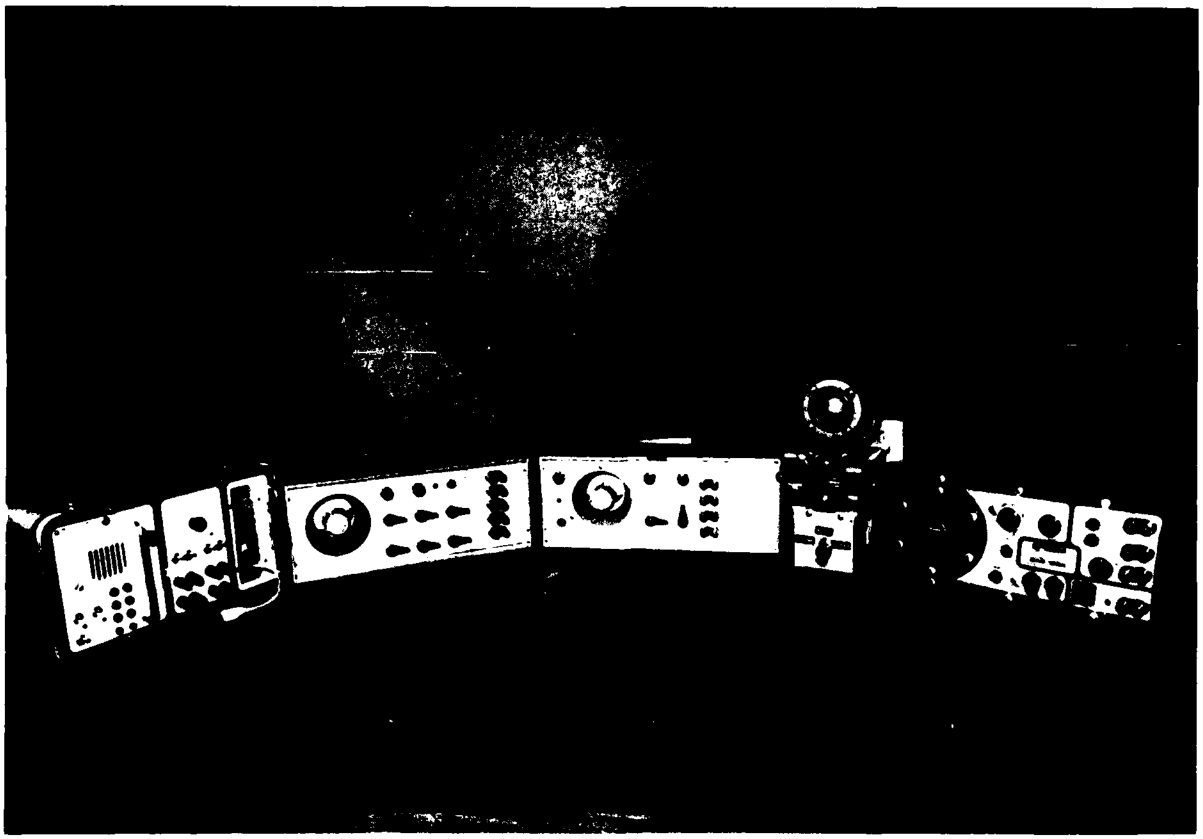

FIGURE 1. The five Hardwire Communication Systems evaluated for chamber use.

TABLE 1

LIST OF MANUFACTURERS

Manufacturer	Model Number
HELLE ENGINEERING, INC. 7198 Convoy Court San Diego, CA 92111 Telephone (619) 278-3521	3214 Wire Diver Phone and 3220 Wire Diver Phone
AMRON INTERNATIONAL Diving Supply, Inc. 751 West Fourth Avenue Escondido, CA 92025 Telephone (714) 746-3834	AMCOM 2820
EFCOM COMMUNICATIONS SYSTEMS 18851 Bardeen Avenue Irvine, CA 92715 Telephone (714) 752-2891	DAR-1000
ATKINSON DYNAMICS 10 West Orange Avenue South San Francisco, CA 94080 Telephone (415) 583-9845	AD-27H-M2

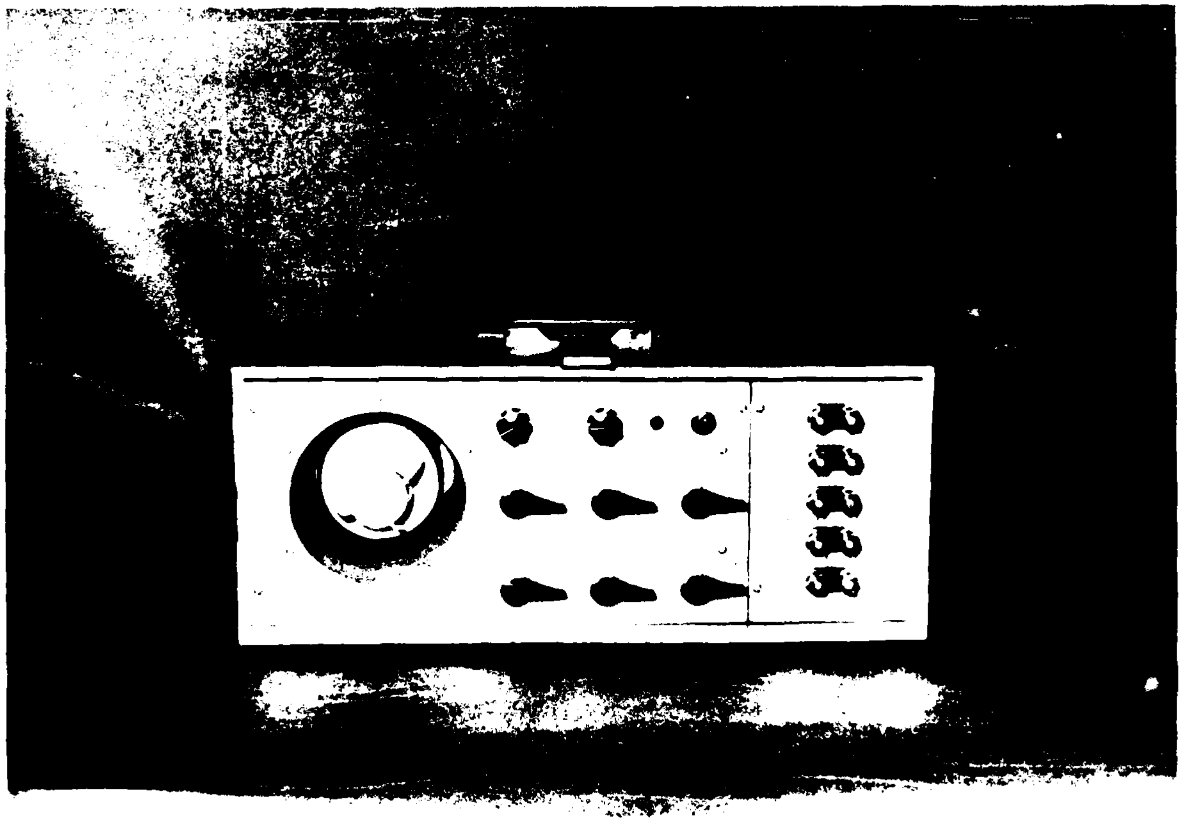

FIGURE 2. HELLE Model 3214 wire diver phone.

TABLE 2. COMMUNICATION SYSTEMS SPECIFICATIONS

Electrical	Helle 3214	Helle 3220	Amron 2820	Efcom DAR-1000	Atkinson Dynamics AD-27H-M2
Power Supply	2 Internal 6 VDC Dry Cells Connect to provide 12 VDC	Same as 3214	4-rechargeable 6VDC Lantern Batteries Connected for 12 VDC built-in recharger	2 6 VDC Drycell Batteries Connected to provide 12VDC	117 VAC, 50/60 Hz
Frequency Response	300 Hz to 12 KHz	300 Hz to 12 KHz	300 Hz to 12 KHz	300 Hz to 15 KHz	300 Hz to 10 KHz
Power Output	2 Watts	6 Watts	12 Watts	8 Watts	8 Watts
Input Impedence	3 to 6 L	3 to 16 L	1 to 600 L	2 to 600 L	8 L
PHYSICAL					
Weight	16 pounds	15 pounds	20.5 pounds	15 pounds	12 pounds (No Batteries)
Dimensions	H:6.6", 8.4", W:16.8"	H:6.6" D:7.9" W:16.4"	H:10",D:9",W:14.5"	H:7.5",D:10",W:16"	H:10.6" D:4.2" W:6.5"
Cost	$1400.00	$710.00	$695.00	$729.00	$350.00

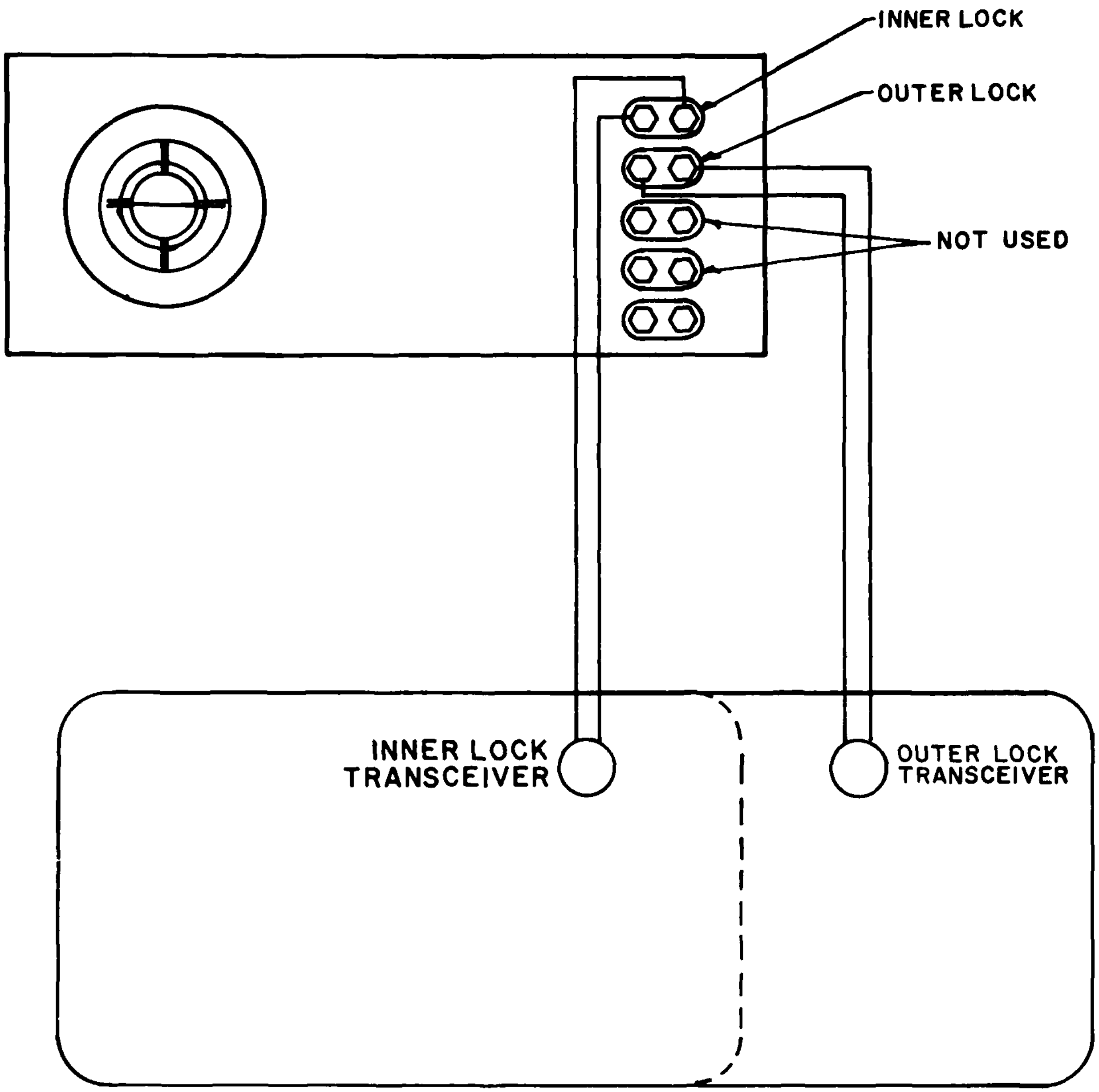

FIGURE 3. Wiring layout for HELLE Model 3214.

HELLE Model 3220 Wire Diver Phone. The HELLE model 3220 wire diver phone (Figure 4) is an intercom system between a surface tender and either one or two divers (in this case personnel inside the recompression chamber, inner or outer lock) at the same time or individually. Specifications for the communicator are shown in Table 2.

The system was packaged in an ABS plastic case with a flat cover of the same material. The front panel was aluminum with silkscreen markings and all connections were made on the front panel. The system as tested was powered by two internal lantern type 6 VDC batteries connected in series to provide 12 VDC to the system. There was a low voltage indicator light on the front panel that illuminated when the system voltage dropped below 7 VDC. The cabinet speaker functioned as both a speaker and a microphone; speakers inside the test chamber provided the same dual function. The system was used in the two wire mode (see Figure 5 for wiring layout).

AMCOM II Model 2820. The AMRON International AMCOM II model 2820 (Figure 6) is a portable diver communications system (tested as a chamber intercom) that operates from internal batteries or an external 12 VDC power source. The system tested had an internal rechargeable battery and could be operated on a 110 VAC power supply. The A.C. power feature was not used during the chamber test but was tested during the bench test. The system was contained in a fiberglass case with a detachable cover made of the same material. The front panel was aluminum with silk screen markings. All connections were made on the front panel. The system was tested in the two wire mode; see Figure 7 for the wiring layout. Specifications for this communicator are listed in Table 2.

EFCOM Model DAR-1000 Diver Air Radio Communications System. The EFCOM DAR-1000 Diver Air Radio (Figure 8) is a communications system (tested as a chamber intercom system) that provides two-way communications from a surface tender to one or two divers. During this evaluation, it was used with the inner and outer locks of a recompression chamber. The speaker on the front panel served as a speaker and microphone and in this test scenario the speakers inside the chamber also served dual functions. The system was powered by two 6 VDC batteries contained in a compartment that had a separate cover placed on top of the system container. The container was constructed of fiberglass, with the protecting battery cover and the main cover also made from fiberglass. The front panel was aluminum with silkscreen type markings. The system was tested in the two wire mode; see Figure 9 for the wiring layout. Specifications for this communicator are listed in Table 2.

ATKINSON DYNAMICS Model AD-27H-M2. The ATKINSON DYNAMICS Model AD-27H-M2 intercom (Figure 10) is a modified industrial intercom built and furnished to Dixie Chamber Co. for use as a chamber intercom. The system as tested operated on 115 VAC power that was internally reduced and rectified to 12 VDC. The system was housed in a cast aluminum case, and the front panel was constructed of the same material with engraved markings. Connections were made at the bottom of the panel. This system was not portable, and was built to be mounted on a bulkhead or in an upright position. The speaker served dual functions as a microphone and speaker. A small interface box with a switch and plugs was built by the test facility in order for the system to be used on the test chamber. The recompression chamber's internal speakers were connected to this interface box and also served dual functions as microphone

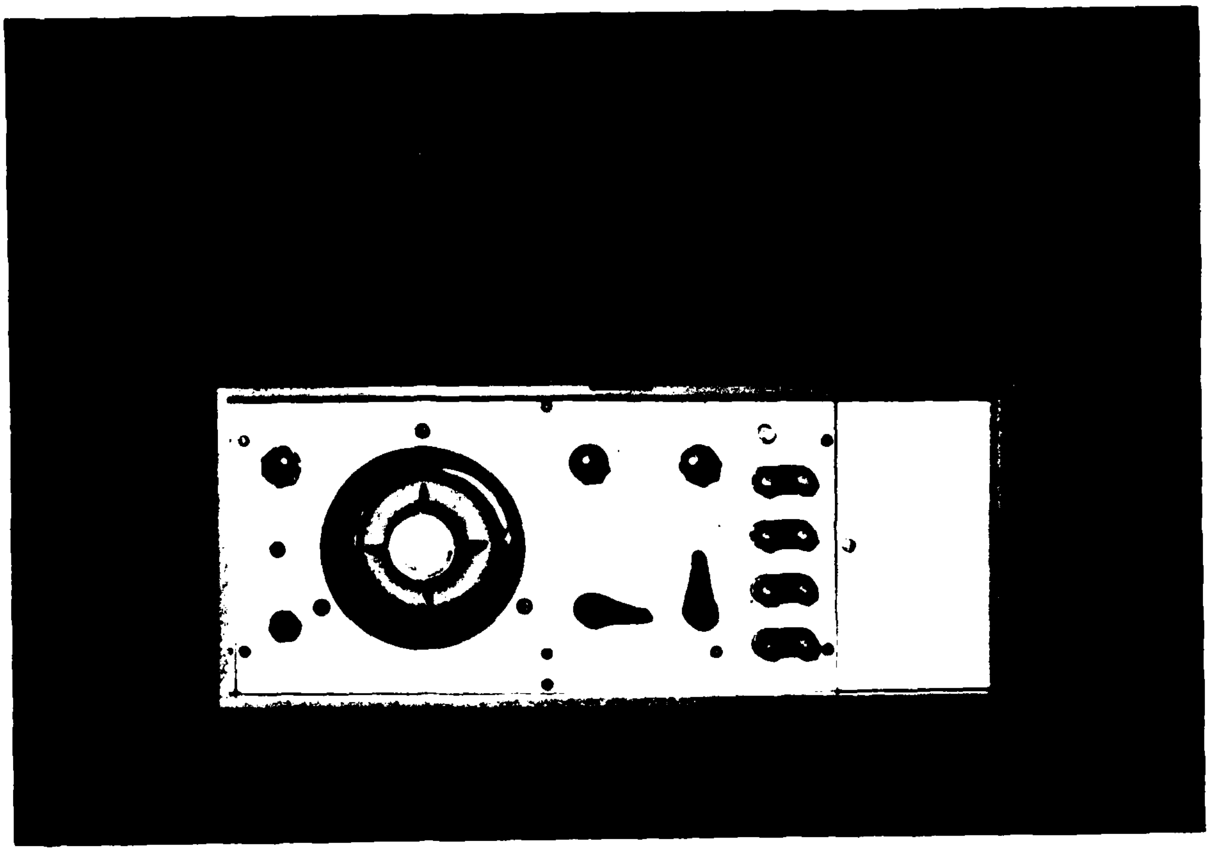

FIGURE 4. HELLE Model 3220 wire diver phone.

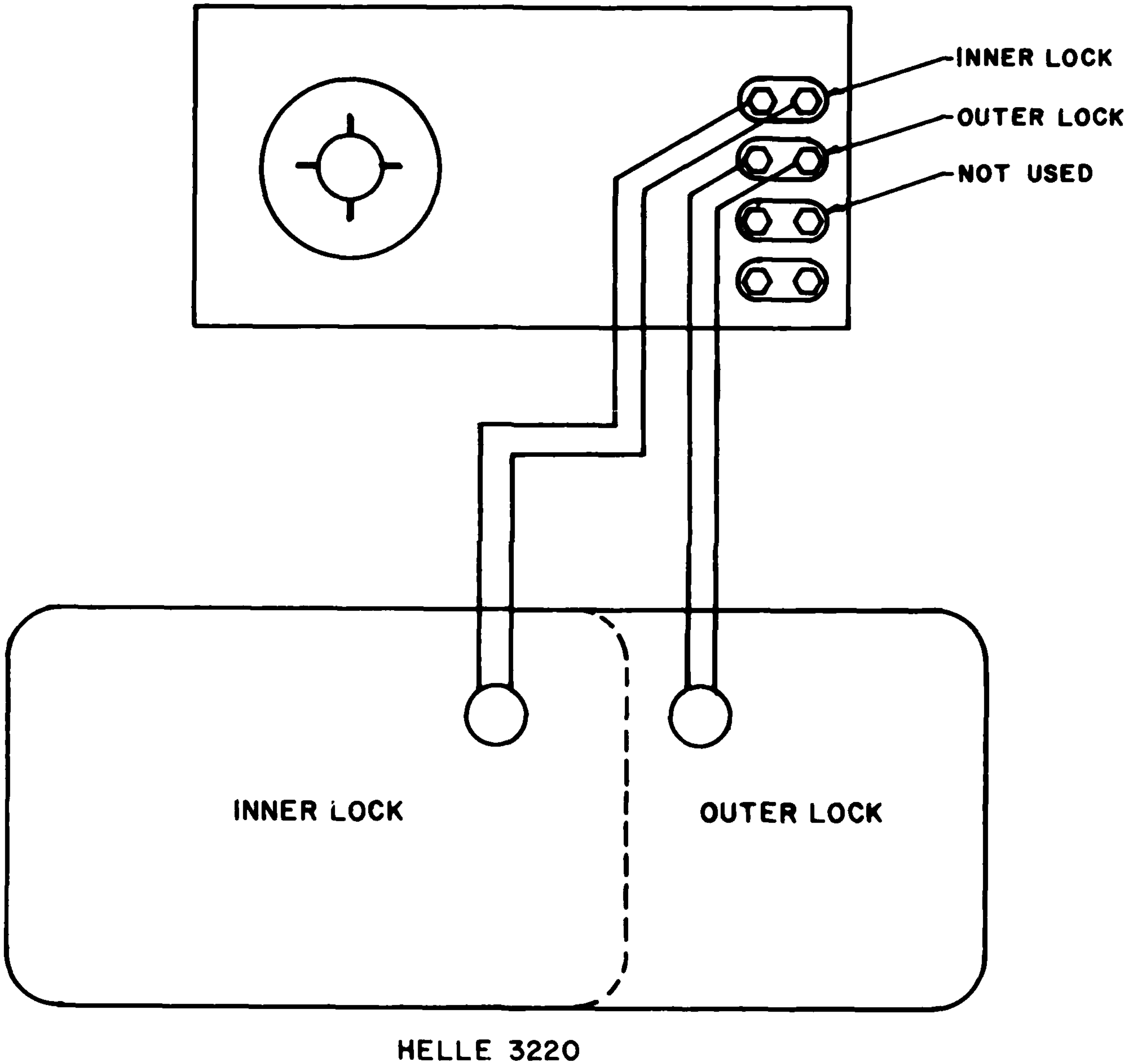

FIGURE 5. Wiring layout for HELLE Model 3220.

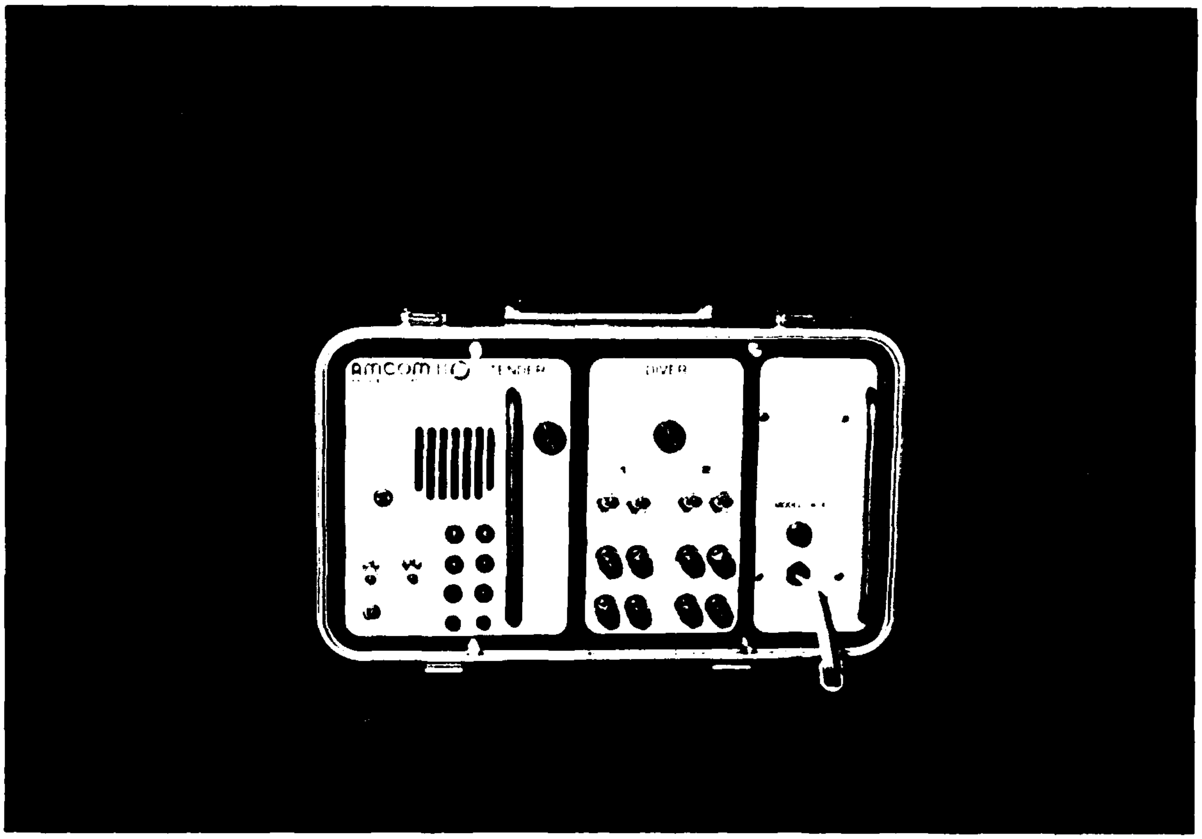

FIGURE 6. AMCOM II Model 2820 portable diver communications system.

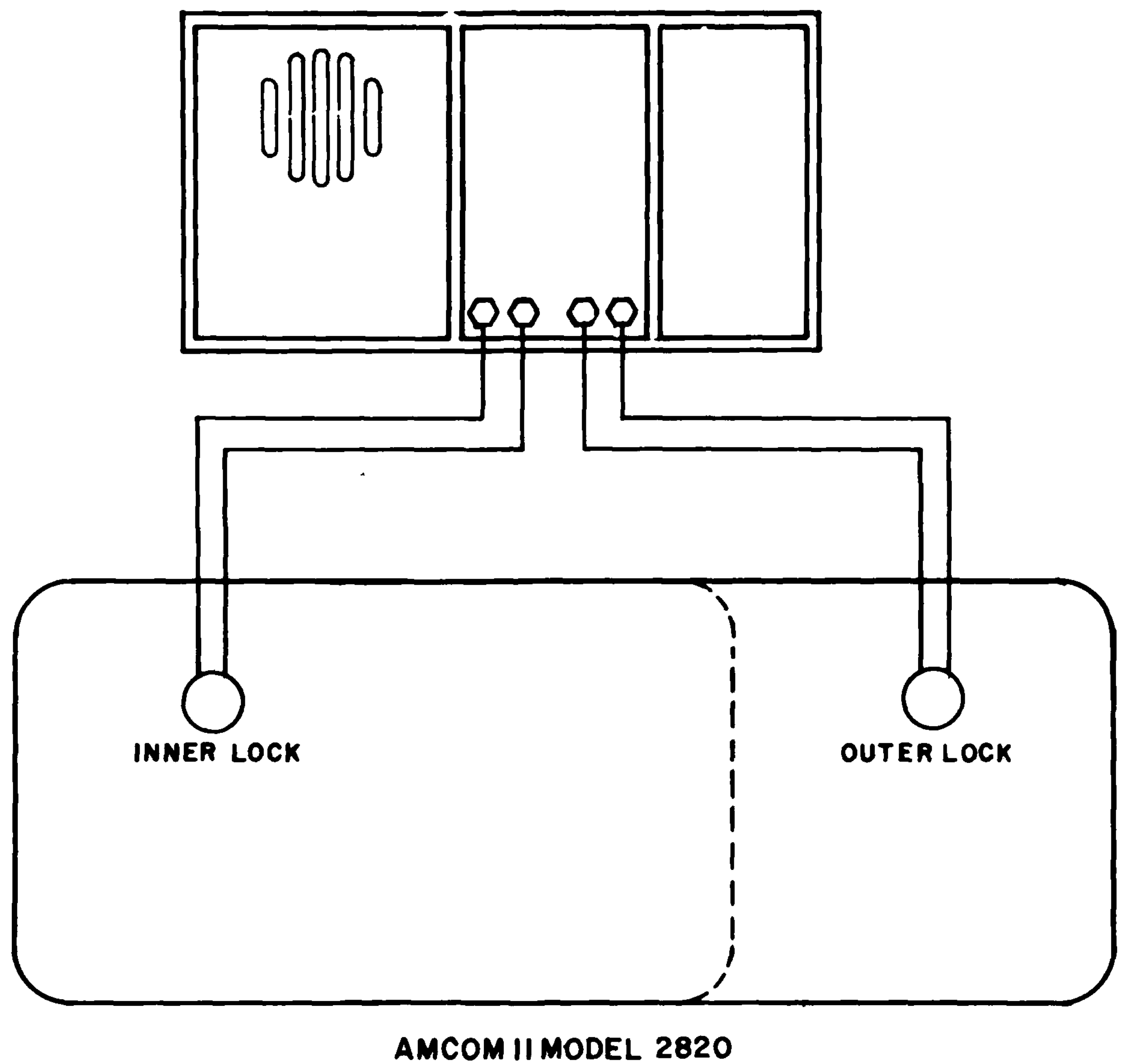

FIGURE 7. AMCOM II Model 2820 wiring layout.

FIGURE 8. EFCOM Model DAR-1000 diver air radio communications system.

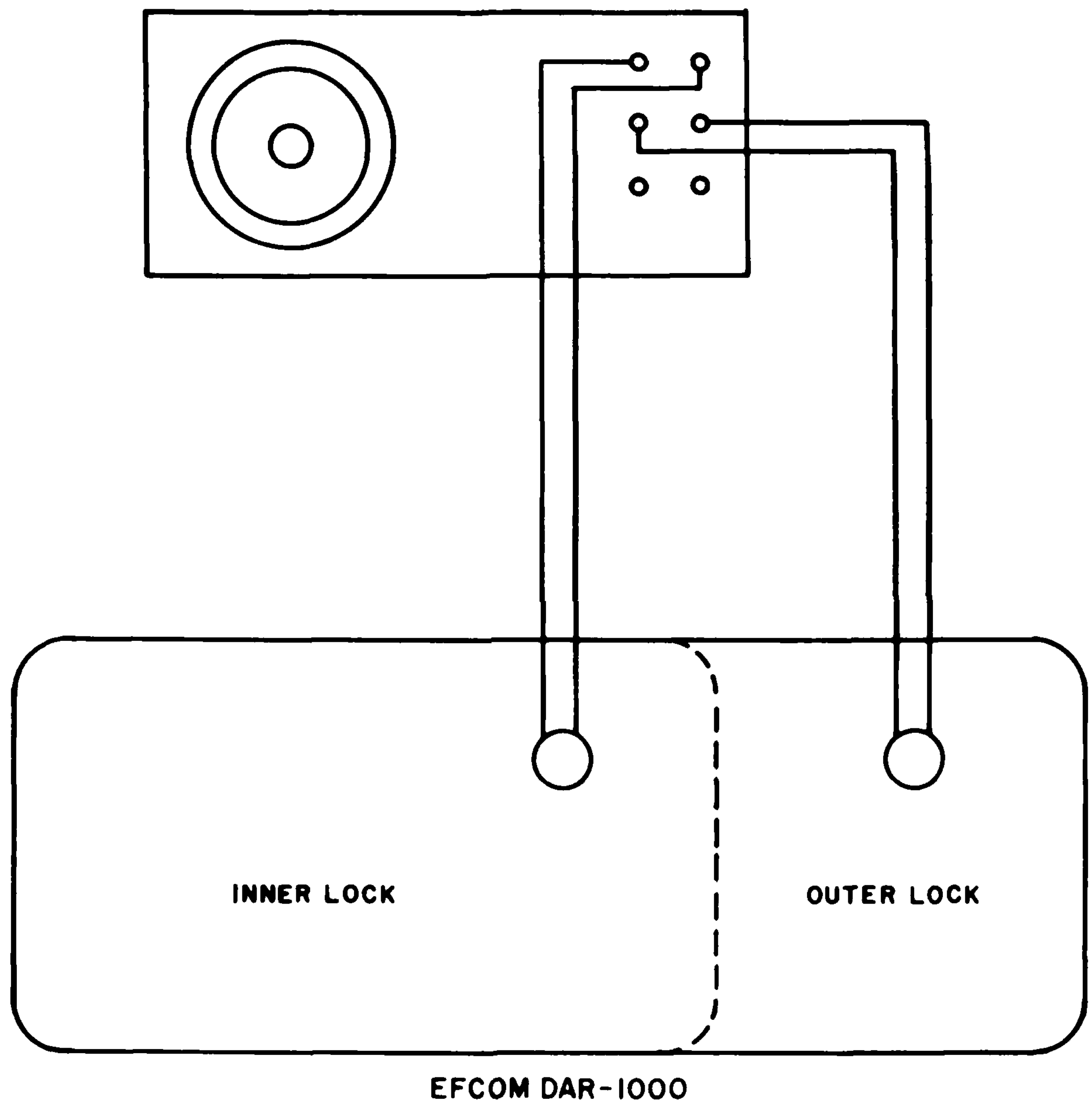

FIGURE 9. EFCOM Model DAR-1000 wiring layout.

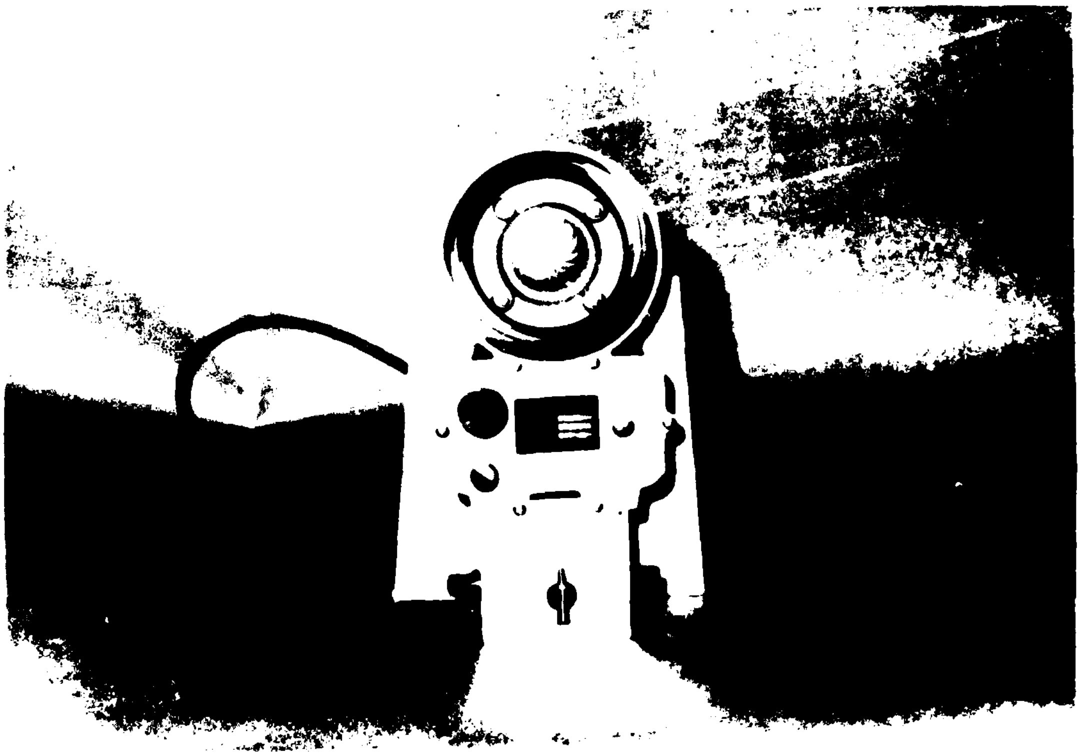

FIGURE 10. ATKINSON DYNAMICS Model AD-27H-M2 intercom.

and speaker; see Figure 11 for the wiring layout. Specifications for this communicator are listed in Table 2.

BENCH TEST
IAW MIL-STD-810C

PROCEDURE

A bench test was conducted in accordance with MIL-STD-810C, procedure V of method 516.Z.

Description of Bench Handling Test (Test #1)

The chassis was removed from its enclosure, as for servicing, and placed on a work bench with a solid wood top 1.75 inches thick.

Step #1 - Using one edge as a pivot, the opposite edge of the chassis was lifted until one of the following conditions occurred:

a. The chassis formed an angle of 45 degrees with the horizontal bench top.

b. The lifted edge of the chassis had been raised 4 inches above the horizonal bench top.

c. The lifted edge of the chassis was just below the point of perfect balance.

In each case when one of the above conditions occurred the chassis was dropped back freely to the horizontal bench top. This test was repeated using each of the practical edges of the same horizontal face as the pivot point, for a total of four drops.

Description of System Check (Test #2)

Step #1 - The system was inspected for possible shock hazards by a visual inspection, followed by a check of components and their makeup, installation, and lay out.

Step #2 - Using a 500 VDC meggar, ground resistance readings were taken on all cables that carried AC power.

Step #3 - Each system was set up on the recompression chamber. The wiring and configuration was the same for each system, if possible, and any deviations were noted and taken into account.

RESULTS OF BENCH TESTS

HELLE 3214

Bench Handling Test

The HELLE 3214 was removed from its case. The front panel was in two parts with a wiring harness between the two so that each panel was subjected to TEST #1 Step #1. Before conducting the tests, the system was inspected for

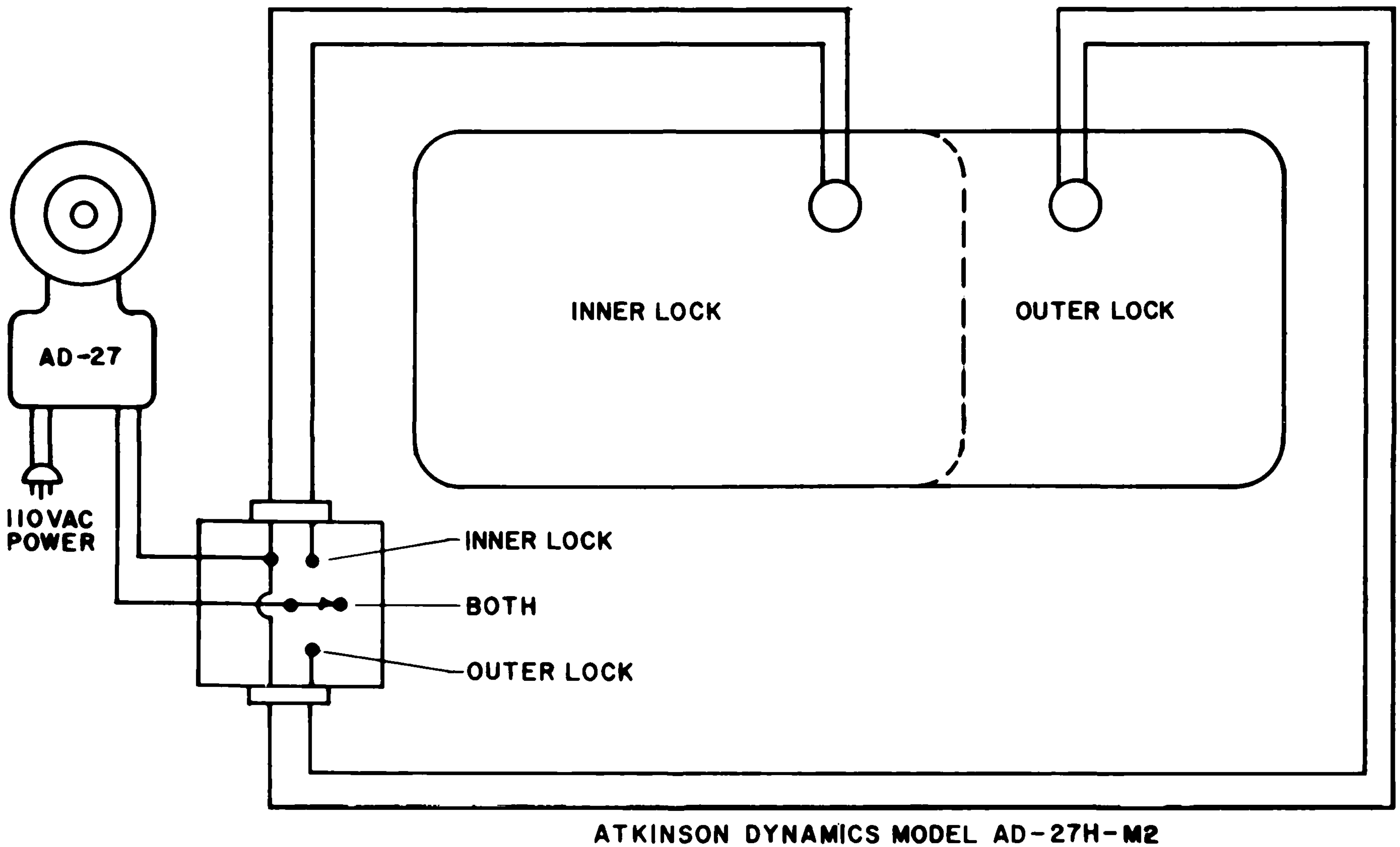

FIGURE 11. ATKINSON DYNAMICS wiring layout.

any visual problems, broken wires, loose components, etc. None were apparent. The system was powered up and the output signals checked. Then TEST #1, Steps #1 and #2 were conducted. Upon completion of this phase of the evaluation, the system was again visually inspected for loose components, broken or damaged wires, etc. None were apparent. Once again, the system was energized and output signals checked out satisfactorily. During the visual inspection of the system, it became apparent that some of the key component part numbers had been removed and that part numbers listed in the manual did not agree with part numbers on the components (i.e. the Printed Circuit Board). The low voltage indicator light also came on when the system was moved or subjected to the slightest vibration while energized. The voltage of the batteries was checked and found to be 12.3 VDC. The low voltage flasher circuit was part of the Printed Circuit Board (PCB) and the wiring diagram provided with the system did not cover the PCB. Consequently, no further troubleshooting was attempted. The system was placed back in its case with fresh batteries. The system was not difficult to remove or replace into its case, although there was one screw located behind one of the cross talk switches (DV 1 & 2).

System Check Test

The internal layout was such that troubleshooting of components would be very difficult. The wiring diagram and parts list indicated one part number on the Printed Circuit Board while the PCB in the system had another number. The wiring diagram provided with the system would also be of little value in repairing the system.

There appeared to be no shock hazards either to the operator, diver or repair personnel. This system, as provided, was powered by batteries with no A.C. power input so ground resistance readings were not taken as part of this test. The system was checked for compatible hook-ups with the test chamber and no alterations were needed in order to conduct the test as planned.

HELLE 3220

Bench Handling Test

The HELLE 3220 was removed from its case. The front panel was in two parts, one of which was the battery compartment cover that was held in place by a lip on the right side and a thumb screw on the left. The main front cover was held in place with six screws, all of which were easily removed. All of the internal components were attached to the main front panel except the batteries to power the system.

Before conducting the bench tests, the system was inspected for any visual damage, i.e. broken wires, loose components, corrosion, etc. None were apparent except for a problem with the batteries which were in the system when it arrived at NEDU. They were badly corroded and discharged. New batteries were connected and the system was powered up and the output signals checked. Then the batteries were disconnected and TEST #1, Steps #1 & 2 were conducted. Upon completion of this phase of the evaluation, the system was visually inspected for loose, broken or otherwise damaged components. None were apparent. The system was again energized and output signals checked out satisfactorily.

System Check Test

Key components on the PCB had identifying markings removed, thus hindering any repairs by users. Also the wiring diagrams provided with the system were for the most part unreadable and of little value as a troubleshooting aid. However, the component layout was simple and most of the components were easy to access. The system as tested was battery powered alone with no A.C. inputs so ground readings were not taken. The system was checked for compatible hook-ups with the test chamber and no alterations were needed in order to conduct the planned test.

AMCOM II Model 2820

Bench Handling Test

The AMCOM II system was removed from its case. This was accomplished very easily as only four thumb screws held the system in its case. However, they were placed at points that hold the system in place evenly. After the four thumb screws were removed there were two handles provided to lift the system from its case. Removal of the batteries was not difficult but some resistance was experienced with one of the batteries because it rubbed the back of the speaker driver as it cleared the battery compartment. Before conducting the bench tests the system was inspected for visual damage and none was apparent. The system was powered up and output signals verified. Power was then secured and TEST #1, Steps #1 & 2 were conducted. Upon completion of this phase of the evaluation, the system was again visually inspected for loose, broken or otherwise damaged components. None were detected. Again the system was energized and output signals checked out satisfactorily.

System Check Test

The system was visually inspected for possible shock hazards and none were apparent. A check of component layout, make up and installation was made and found to be satisfactory in all respects. Along with the physical check of the system a comparison between the parts lists, drawings and actual components was made. The results were that the parts list and drawings were very good with no discrepancies between the software and the actual hardware. The manual would provide the necessary guidance for user maintenance to be conducted by U.S. Navy personnel with an electrical background.

Using a 500 VDC meggar, ground resistance readings were taken on the A.C. power lead with the proper readings recorded. Following the bench tests, the system was placed back in its case. No configuration changes were required in order for the system to be tested on the recompression chamber.

EFCOM DAR-1000.

Bench Handling Test

The EFCOM DAR-1000 system was removed from its case. This was accomplished by removal of six screws from the face, each having lock nuts on the back lip of the case front. The was followed by removal of four more

screws from the back side of the front lip that were screwed into the handles. The system was then lifted out of the outer case by grasping the speaker and the diver connections. This removal could be simplified if the screws holding the handles in place did not penetrate the outer shell. The other six screws were more than adequate to hold the communicator in place and afford a splash tight configuration.

Before conducting the bench tests the system was inspected for any visual damage and none was apparent. Following this inspection, the system was subjected to the chassis drop tests with no problems noted.

System Check Test

The system was visually inspected for possible shock hazards. None were observed. Internal components were easy to access for troubleshooting and upon checking the manual, parts list, and drawings, it was determined that the system was user maintainable by Navy personnel with electrical backgrounds. Upon completion of this phase the system was placed back in its container, energized and its output signals checked out satisfactorily. No configuration modifications were required in order for the system to be tested on the recompression chamber.

ATKINSON DYNAMICS AD-27H-M2

Bench Handling Test

The ATKINSON DYNAMICS AD-27H-M2 system was constructed in such a way that it was not completely removable from an outer container since the entire system including speaker was housed in a sealed, submergence-proof cast aluminum case. With the removal of six screws, the front plate could be lifted and there was sufficient wiring to allow it, with the main components attached, to be laid over for repairs/troubleshooting. With the system in the open state and the front panel laid to one side with one screw holding it to the housing face down, TEST #1, Steps 1 & 2 of the bench testing were conducted without any visible damage. Upon completion of this phase, the system was placed back into its container, energized, and its output signals checked out satisfactorily.

System Check Test

The system appeared to be safe to the operator and by using accepted practices by qualified personnel, safe to repair and troubleshoot. The schematic provided with the system appeared to be very accurate. There was no parts list with the operating manual but the system was simple enough that the material provided was satisfactory.

Ground readings taken on the A.C. power cord indicated safe readings between all conductors. Upon completion of the bench tests and the system checks, an interconnect box was built so that during the manned testing communications could be carried on with both the inner and outer lock of the recompression chamber. This interconnect box consisted of a selector switch and two banana jacks in order to use the same connecting cable on all of the systems tested. This modification would be required in order to use this system on any Navy double lock recompression chamber.

Summary of Bench Test and Evaluation Checks

While all of the systems were found to have some discrepancies, all were found to be safe to operate as designed. The most significant problems were found to be in the area of maintainability, i.e. troubleshooting and repair in the field by Navy Technicians. The Helle models 3214 and 3220 both had shortcomings in this area in that there were several key components that were unidentified because their markings had been removed. Further, the Helle manuals were incomplete and inaccurate, and the system schematics were difficult to read.

The Atkinson Dynamics System did not come with a manual; a Sales and Specification sheet and a package of System Drawings/Schematics accompanied the unit. However, there was sufficient material to troubleshoot the system and make repairs if necessary. The AMRON and EFCOM Systems both were accompanied by very good manuals, drawings and schematics. Included in both packages was a complete parts list. The Atkinson Dynamics AD-27H-M2 was the only system that had to be modified in preparation for the manned test on the recompression chamber. This modification, previously described in the text of this report, would be required on U.S. Navy double-lock chambers.

During the course of testing, only one system, the Helle 3214, experienced a failure. The failure is described elsewhere in this report. The other systems proved reliable during the limited time each was operational. In particular, the AMRON model 2820 and the EFCOM DAR-1000 were accompanied by very good reference literature. Workmanship was of high quality in these two systems. These features are good indications of a reliable product. Lastly, linked to the concept of reliability is the life cycle cost of each system. Based on the purchase price of each system and the reliability exhibited during this evaluation, the AMRON model 2820 and the EFCOM DAR-1000 should have the most favorable life-cycle costs.

HUMAN FACTORS EVALUATION OF SYSTEM CONTROLS

Procedure:

A human factors evaluation of each communication unit was undertaken to assess the areas of control coding, control designation, control resistance, control location and control feel. These areas influence operator efficiency and accuracy, which in turn effects the efficiency of the communication system and the safety and performance of the chamber occupants. For a further discussion of the principles of control design, the reader is referred to Van Cott and Kinkade (1972).

RESULTS

The following observations were noted for each unit:

HELLE MODEL 3214

Coding and Designation

(1) The "press to cross connect" switch label was under the appropriate switches, whereas the "press to talk" labels were placed above their respective switches, resulting in non-conformity of label positioning.

(2) "Diver 1 to" label was not adequately grouped near the bottom legends; the lettering should be closer to "Divers 2 and 3".

(3) The black 3mm high coding letters showed up well on the silver gray background.

(4) There was no directional indication on the diver's volume control.

Location Variables

(1) The "press to talk" toggle switch was in the upper right hand corner. As this is the most frequently used control, it should be located closer to the speaker because it is activated when the person talks into the speaker.

(2) Volume controls were grouped together nicely, as were the "press to talk" and "press to cross connect" levers.

(3) The hardwire inputs were appropriately labeled.

(4) The physical spacing between the adjacent "press to talk" levers was less than the minimum required in the horizontal plane. Minimum recommended distance is a 5.8 cm radius around a control (Van Cott and Kinkade, 1972); actual radius was 4.6 cm between adjacent levers. The operator's fingers (e.g. middle finger) contacted adjacent levers when using thumb and forefinger operation.

Resistance and Feel Characteristics

(1) None of the press levers provided indication of positive activation. All press levers required 2 finger operation with no positive detent on these controls. A "grating" resistance was felt by the operator.

(2) The "press to talk" toggle switch provided good positive feedback to the operator via a detent and was covered to prevent dirt and moisture contamination. One finger was all that was required to operate this switch.

(3) The "tender volume" knob had a positive on-off action. The "divers volume" knob had no positive detent, but positive stops. When these volume control knobs were placed in the fully open position, three operators reported that the knobs were in the "off" position.

HELLE MODEL 3220

Coding and Designation

(1) The speaker toggle switch did not have an "off" label.

(2) Color coordinated plug inlets were provided for the 12 VDC external power source.

Location Variables

(1) The "press to talk" lever position and that of the "cross talk" lever were suitable only for a right-handed operator.

(2) The "press to talk" lever was physically located too close to the "cross talk" lever.

(3) The "cross talk" lever was located too close to the hardwire inputs. Operation of this lever also required two fingers, and the operator's hand would cover, rub against, or interfere with the hardwire input entry. Cuts and abrasions to the hand may result.

Resistance and Feel Characteristics

(1) There was no positive evidence of actuation (e.g. detent) when operating the "press to talk" lever.

(2) The "cross talk" lever provided just discernable audio and tactile feedback. However, each lever on the unit tested provided different points of feedback dependent upon whether the operator was pressing or releasing the lever.

(3) The "speaker" toggle switch provided a good detent for feedback to the operator.

(4) The "tender volume" knob had a positive on-off mode and stops.

(5) The "diver volume" knob did not provide positive on-off feedback, but did provide a positive stop.

(6) The "press to talk" lever had excessive resistance for single finger operation. Should the operator attempt to use two fingers, the wrist of the operator will be placed in a strained, awkward position.

AMCOM II MODEL 2820

Coding and Designation

(1) This unit incorporated good grouping of diver and tender controls by using black colored bands for separation.

(2) Directional indications and on/off codes were not provided on the tender and diver volume controls.

(3) The diver "push to talk" switches labeled "on" and "off" were somewhat misleading because on the tender side the switch with the same function was labeled "push to talk".

(4) "Push to talk" switches are more appropriately labeled "depress to talk".

Location Variables

(1) To activate the diver crosstalk momentary switch, the operator's hand rested against the hardwire input/output connections, raising the spectre of injury to the hand and displacement of wires.

(2) The diver crosstalk controls were placed non-sequentially in a horizontal row (i.e. on-crosstalk-crosstalk-on) rather than in a sequential fashion (i. e. on-crosstalk-on-crosstalk). The present configuration was confusing.

(3) The "power on", "speaker on", and "push to talk" switches on the tender panel were all in the same location, of the same configuration, and in very close proximity to each other. Control confusion and inadvertant activation by the operator are a distinct possibility.

(4) The carrying handle on the tender side of the unit was immediately adjacent to the microphone. This physical obstruction could result in decreased or altered sensitivity, and also interfere with the operator's line of sight for the wiring labels.

(5) Placing the front AC plug on the lower right hand side necessitated a connection with a power supply in an exposed position.

Resistance and Feel Characteristics

(1) All toggle switches had positive feedback and required one finger operation only, with a positive return action on the "push to talk" switches.

(2) The volume controls had no positive on-off detents. However, they did have positive stops and were easy to rotate with thumbs and forefingers.

(3) Finally, a right handed operator must talk over his right arm and into the speaker when operating the "push to talk" switch in the tender panel.

EFCOM DAR 1000

Coding and Designation

(1) The panel face was blocked off by blue and black lines, but was not grouped either by function or components. The layout of the controls appeared arbitrary and the graphics were for aesthetics alone.

(2) "Push to talk" switches should be labeled "depress to talk".

(3) The label for "diver speaker" located above the diver selector knob was the same letter height and distance from the control knob as were the functioning labels. The labeling used did not discriminate selector position from selector label.

(4) The "Crosstalk" label was difficult to read in the vertical plane. The placement of the crosstalk labels (i.e. "Diver 1 to 2", "Diver 2 to 1") were equidistant or closer to the hardwire inputs than to their respective crosstalk switches.

(5) The diver volume controls had no "on" or "off" labels.

(6) The EFCOM signature label and graphics take up considerable space which could be used for functional operations.

Location Variables

(1) There was good spacing between the tender volume and diver speaker rotary knobs.

(2) Inadequate spacing existed between the diver volume knob and the earphone hardwire input.

(3) The crosstalk switches and the push to talk switches were in good position concerning clearances for the operator's hand.

Resistance and Feel Characteristics

(1) All toggle switches had a positive detent and provided feedback to the operator.

(2) The crosstalk toggle switches were of different colors and in different locations. However, the horizontal activation of switches was unusual and may cause confusion and/or breakage.

(3) The tender volume knob had a positive "on-off" detent, whereas the diver volume knob had no positive "on-off" detent. Further, the graphics did not indicate the position of full on and full off, and there appeared to be excessive rotation of the knob (approximately 80% full circle).

(4) The "push to talk" toggle switch required excessive force to activate and keep depressed.

(5) The crosstalk toggle switches will generally call for two finger operation (thumb and forefinger) and require a strong force to operate.

(6) Dust covers on the toggle switches and spring covers on the microphone and headset were good protective devices.

ATKINSON DYNAMICS AD-27H-M2

Coding and Designation

(1) This unit had silver letters, 4 mm high, etched into the console face. These letters (labels) were located above their respective controls.

(2) The "power" and "audio" labels should have a directional arrow beneath each label pointing to where the cables enter the unit.

(3) There was no "on-off" indication or labeling to direct the operator how to turn the unit on or off.

(4) No arrow indicator or pointer was furnished on either the "local" or "remote" volume knob to indicate control setting and/or direction.

Location Variables

(1) The toggle switch for "talk" was centered on the right side of the console in a good position for right-handed operators.

(2) Both volume knobs were located on the left side of the console, grouped nicely, but closer together than optimally desired (5.8 cm radius desired; 3.5 cm radius obtained).

(3) A clean, uncluttered console face was provided.

Resistance and Feel Characteristics

(1) The "listen-talk" toggle switch had a faint positive detent and a protective dustcap.

(2) A positive on-off detent and stop was provided for the local volume knob.

(3) The remote volume knob had no positive on-off detent.

SUMMARY

To varying degrees all units reflected their manufacturer's efforts at control coding, location and activation. As was evident from the results of the human factors evaluation, however, all units fell short in several areas. Inadequate spacing between controls, inappropriate labeling, lack of positive feedback on controls, and failure to protect the operator's bare hand from accidental cuts and scrapes were the most prevalent discrepancies noted. All of the documented human factor control discrepancies appear to be easily correctable by the manufacturers with careful prior planning design. Most important, no human factor control discrepancies were noted on any unit which were serious enough to warrant a unit failing this portion of the evaluation.

OPERATIONAL MANNED TESTS

PURPOSE

This portion of the evaluation was conducted to test the communicators in the actual environment in which the communicators would be used.

METHOD

Subjects

One female and five male U.S. Navy divers, all volunteers and in good health, served as test subjects. Auditory acuity levels of all diver-subjects

as assessed by an audiogram within the last nine months were within limits outlined in Article 15-11 of NAVMED P-117. Subjects did not exhibit any noticeable articulation problems, unusual dialects or speech deficits.

Intelligibility Test [Modified Rhyme Test (MRT)]

Following the guidelines set forth in NEDU Test Plan 83-28, each of the test communication systems was set up on a double lock recompression chamber with three listeners on the inside of the inner lock of the chamber and three listeners on the outside. Close attention was paid to insure that listeners were sitting in the same location for the tests conducted on each system. These tests were conducted twice on each communication system at each of the following depths: 0, 60 and 165 feet of sea water (FSW). Twenty-five words were read from the MRT word lists vice 50 words to minimize overall bottom time and decompression time for the divers. A sample MRT is included in Appendix A.

Procedure

All divers wore flame-retardant clothing and were seated side-by-side in designated places inside the chamber. Each diver carried a clipboard and a MRT response or reading sheet as appropriate. Diver and outside operator locations were set in the same position for each test, with the readers of the MRT always in the center position. Positions are shown in Figure 12. Speakers were rotated 1-2-3-1-2-3 on each dive team. Communicator tests were sequenced to ensure that no communicator immediately followed another communicator on both trials. The volume of both the inside and outside speakers was adjusted to the listeners' preference before each test started. The carrier sentences containing the designated MRT words were delivered at the rate of one every five seconds.

Interior and exterior chamber lighting was kept constant, as was communicator placement on a desk outside the chamber and operator seat positions. The area around the chamber was kept clear, and control was exercised over noise sources such as talking, door slamming, etc. to prevent distractions and loss of data. Identifiable, uncontrolled noise sources that occurred during testing included intermittent telphone ringing, elevator operation, paging over an intercom, operation of gas compressors in an adjoining facility, and occasional helicopter landings 200 yards away.

Compression of the chamber on air was accomplished at a rate of 75 feet per minute to depths of 60 and 165 FSW. Testing was conducted at 165, 60 and 0 FSW. The chamber was ventilated upon reaching each test depth before testing started. A carbon dioxide scrubber was running during compression and decompression, but not during testing. During each test, the reader and one listener on the outside team filled out a questionnaire on the communciator they were using. The standard internal transceiver (speaker) was used inside the chamber in all cases. These transceivers serve a dual function as a microphone for transmitting and as a speaker for receiving. The transceivers used had a value of 8 Ohms at the communicator system.

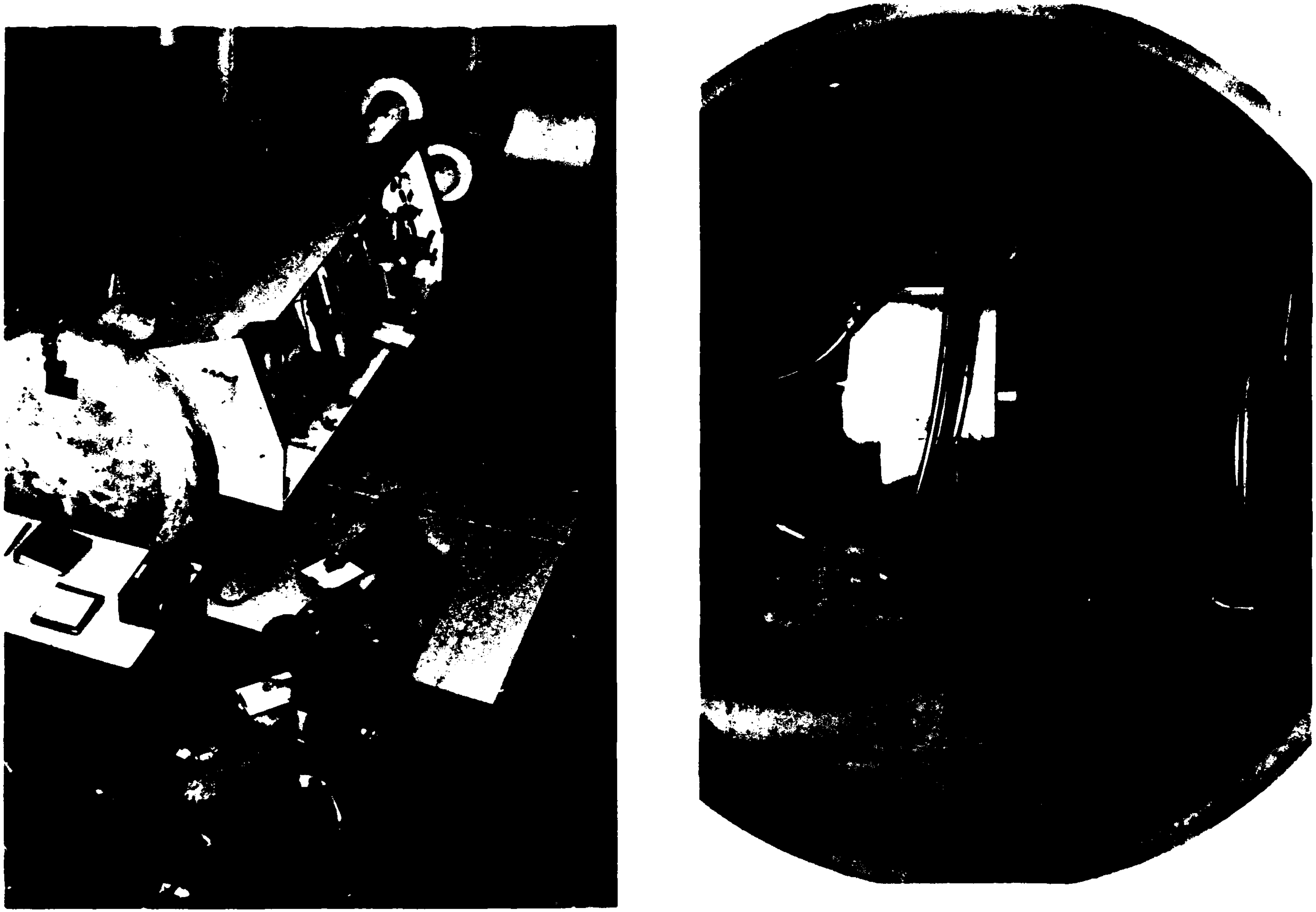

FIGURE 12. Diver and outside operator positions during the evaluation.

Results

The formula used for scoring the MRT was: % correct = (no. right-$\frac{\text{no. wrong}}{4}$) x 4. Temperature ranges inside the chamber during testing (and after venting) were as follows: 0 FSW (70-78°F); 60 FSW (72-82°F); 165 FSW (78-87°F).

Four of the five communicators met or exceeded the minimal acceptable intelligibility score of 75% for the MRT as set forth in MIL-STD-1472B; the Helle 3214 did not meet this criteria. The following overall speech intelligibility scores on the MRT were recorded for each system: Helle 3214-62%; Helle 3220-86%; AMCOM II-80%; EFCOM 1000-84%; AD-27H-M2-77%.

A two-way repeated measures analysis of variance (Myers, 1972) was conducted to determine the significance of the differences among the mean correct word scores recorded by communicator units on the MRT. Significant differences among communicators were found [$F(4,20) = 12.76$, $p < .01$], as well as among test depths [$F(2,10) = 12.42$ $p < .01$].

Subsequent tests were performed among the means using Duncan's Multiple Range Test (Bruning and Kintz, 1968). These tests found that the Helle 3214 was significantly poorer overall ($p < .01$) than any of the other communicator units in word intelligibility; none of the other communicators differed significantly from each other. A similar analysis was performed on the combined mean communicator scores at each depth. Significant improvement ($p < .01$) in word intelligibility was found between 0 and 60 FSW, and between 0 and 165 FSW. There were no significant differences in word intelligibility between 60 and 165 FSW.

Figure 13 shows the mean number of correct responses by divers on the MRT by unit at the test depths. A significant depth/communicator unit interaction was present [$F(8,40) = 29.02$, $p < .01$]. Whereas the number of correct answers rose steadily for four of five units from 0 to 60 FSW, two of the five units (EFCOM and Helle 3220) showed a decrease in intelligibility as the depth was increased to 165 FSW. The other units either increased in intelligibility (AMCOM and Helle 3214) or remained stable (AD). It should be noted that the magnitude of the loss of intelligibility was not enough to fall below surface levels recorded from these units except for the Helle 3214, the performance of which was poorer at 60 FSW than at the surface. Correct responses of all subjects on all communicators were consistently lower when recording on the outside of the chamber ($\bar{x}$ = 72.6% correct; SD = 12.4%) than when recording on the inside of the chamber ($\bar{x}$ = 91.5% correct; SD = 4.4%).

During the manned dives the operators kept a log and two outside personnel completed questionnaires on each unit tested. (See Appendix B for a sample of the questionnaire used). Operator ratings of each unit on human factors variables are presented in Table 3. The AMCOM II was rated the best communicator overall on human factors variables by the operators, and also scored highest in 4 of the 5 specific areas. The AMCOM II also was rated substantially higher on clarity of sound when compared to all other units. The EFCOM 1000 communicator received high marks in 4 of 5 areas and was ranked overall as the second best communicator. The Helle 3220 and the AD-27H-M2 ranked third and fourth, receiving satisfactory evaluations on human factors

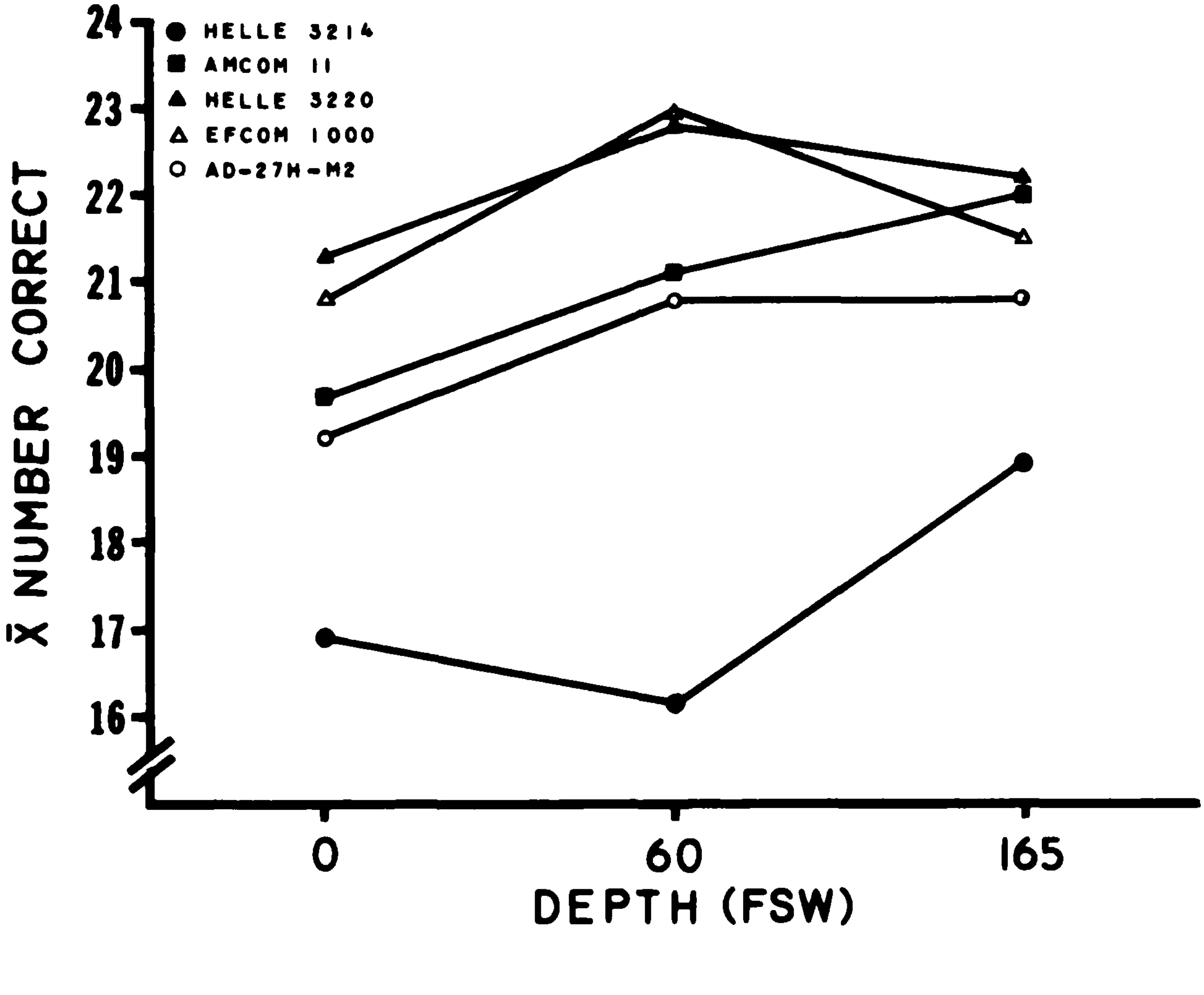

FIGURE 13. Mean number of correct responses by divers on the Modified Rhyme Test by unit at test depths.

TABLE 3. OPERATOR RATINGS OF EACH COMMUNICATOR ON HUMAN FACTORS VARIABLES ($\overline{X}$;SD)

KEY: 1 Poor | 2 Below Average | 3 Satisfactory | 4 Above Average | 5 Excellent

	AD 27HM2	EFCOM 1000	AMCOM II	HELLE 3214	HELLE 3220
Rate the ease of operation of controls on the communicator:	3.5(0.5)	3.8(0.5)	4.3(1.0)	2.8(1.3)	3.3(0.5)
Rate the location of controls on the communicator:	3.0(0.8)	3.8(0.5)	3.8(1.0)	3.0(0.0)	3.5(0.6)
Rate the clarity of sound received through the communicator from inside the chamber:	3.5(1.0)	3.0(0.8)	4.3(1.0)	1.0(0.0)	3.5(1.3)
Rate the construction (i.e. materials, craftmanship) of the communicator:	3.0(0.8)	4.0(0.8)	4.0(0.8)	3.0(1.4)	3.5(0.6)
Rate the aesthetics of the communicator:	3.0(1.6)	4.0(0.8)	3.8(1.0)	3.0(0.8)	3.5(0.6)
Overall Ranking:	4	2	1	5	3

aspects. The Helle 3214 unit received unvarying poor ratings on clarity of sound and was rated below satisfactory on ease of operation of controls.

A summary of the operator's human factors observations is presented in Table 4. Noteworthy responses are found for the AD-27H-M2, where there was confusion in operating controls, and for the Helle 3220, where there was a problem in the labeling of the equipment. It was in responses to the question concerning the operator's confidence in equipment performance that the Helle 3214 fared most poorly. Three of four operators responded that they did not have confidence in the performance of this unit.

From the log kept during the manned testing, the following notes were recorded concerning the performance of each communication unit.

HELLE MODEL 3214. The Helle Model 3214 was the first and last system to be tested during the manned dives in the recompression chamber. The system scored very poorly on the intelligibility test with the chamber occupants reading to listeners on the outside of the chamber. On the surface, words tansmitted through the unit came across garbled. During compression, there was loud feedback from the unit. At 165 FSW, the words read from inside the chamber were transmitted with an echo, were "broken", and the unit produced a "tinny" sound. During decompression, the operators had to switch to the auxiliary sound powered phone to communicate because of the extremely garbled transmission. It is felt that this problem was mainly caused by distortion due to a problem in the tender portion of the amplifier circuit. The speaker was examined and found to be satisfactory; no further troubleshooting was possible due to the manual and drawings provided being incomplete and identifying markings of components had been removed by the manufacturer.

The scores of the intelligibility test for outside personnel reading to chamber occupants were comparable to the other systems tested.

HELLE MODEL 3220. The Helle Model 3220 was the fifth and eighth system to be tested during the manned dives in the recompression chamber. This system scored very well on the intelligibility test both with the chamber occupants reading to the outside listeners and with the outside readers reading to the chamber occupants. This system produced a somewhat "tinny" sound, which at times was also accompanied by broken words (interrupted speech).

AMRON MODEL AMCOM II 2820. The AMCOM II 2820 was the second and seventh system to be tested during the manned dives in the recompression chamber. This system yielded a passing score on the intelligibility test both with chamber occupants reading to the outside listeners and with the outside readers reading to the chamber occupants. This unit had a tendency to exhibit feedback problems during compression which sounded like a "diesel horn."

EFCOM MODEL DAR-1000. The EFCOM Model DAR-1000 was the fourth and ninth system to be tested during the manned dives in the recompression chamber. This system yielded a good score on the intelligibility test both with the chamber occupants reading to the outside listeners and with the outside readers reading to the chamber occupants. The unit exhibited good volume, with some vibration and echos received from the outside speaker.

TABLE 4. SUMMARY OF OPERATORS' HUMAN FACTORS OBSERVATIONS

	AD 27HM2		EFCOM 1000		AMCOM II		HELLE 3214		HELLE 3220	
	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO
Do your fingers ever slip off any of the controls?	0	4	1	3	1	3	0	4	1	3
Do the controls on the communicator give a positive indication of activation (i.e. snap feel, audible check)?	3	1	4	0	4	0	3	1	3	1
Do the communicator labels clearly and correctly describe the equipment?	3	1	3	1	4	0	4	0	2	2
Are the labels of the communicator located on or near the items which they identify, so as to eliminate confusion with other items or labels?	3	1	3	1	4	0	4	0	4	0
Did you ever reach for, or operate, the wrong switch or knob?	2	2	1	3	1	3	0	4	1	3
Do you have confidence in the performance of this equipment?	3	1	4	0	3	0	1	3	4	0

ATKINSON DYNAMICS MODEL AD-27H-M2. The Atkinson Dynamics Model AD-27H-M2 was the third and sixth system to be tested during the manned dives in the recompression chamber. The system's score on the intelligibility test was barely passable, mainly due to insufficient volume both inside and outside the chamber. The entire tests were conducted with the volume controls set on maximum. All test subjects were observed leaning forward in their seats to listen to the transmissions, even with minimal background noise present. Good transmission clarity was exhibited on the surface, and there was an absence of "squealing (feedback)" noted during compression.

OVERALL SUMMARY AND CONCLUSIONS

The five commercially available hardwire communication systems were evaluated side-by-side in a series of tests designed to assess their reliability, operability, safety, and intelligibility. These tests included bench handling, system checks, human factors assessment of controls, operational clarity, and operator use. No communication system was free from defects as assessed by the evaluation. However, three systems possessed deficiencies serious enough to prevent them from being considered for use by the U.S. Navy. The Helle Model 3214 failed to obtain a minimum acceptable level of speech intelligibilty at any depth tested, had key component numbers removed from the chassis, was difficult to troubleshoot with the limited information provided in the wiring diagram, and did not win the confidence of the operators. The Helle Model 3220 also lacked adequate schematics and information for even the most basic repair functions and thus was not recommended for use because of the discrepancy. While the Atkinson Dynamics Model AD-27H-M2 system met the minimum criteria for speech intelligibility, the volume of the system was insufficient to carry sound to the operator's ears at a distance of three feet or more. In addition, modifications would have to be made in order to mount this system to recompression chambers.

Two systems (AMRON Model AMCOM II and EFCOM Model DAR-1000) met all of the basic requirements outlined in the bench, human factors, and operational subtests. The operators rated these two units highest on human factors variables, and indicated that they had confidence in the performance of these units. Both units scored well in the speech intelligibility portion of the evaluation, and came with adequate information for repair and troubleshooting. These two systems should also prove to be reliable and, in conjunction with their other merits, should have the lowest life cycle costs of the units evaluated. Additional consideration of the human factors aspects of system controls by the manufacturers of these units would result in safer, easier to operate units, but the units are considered satisfactory in their current configuration for Navy use.

REFERENCES

1. Bruning, J. L. and Kintz, B. L., Computational Handbook of Statistics. Glenview, IL. Scott, Foresman and Company 1968.

2. Myers, J. L., Fundamentals of Experimental Design. Boston, MA. Allyn and Bacon, Inc. 1972.

3. NAVSEAINST 9597.1.

4. Operation and Maintenance Manuals, provided by each manufacturer of systems tested.

5. MIL-STD-810C.

6. NEDU Test Plan 83-28.

7. U.S. Navy Manual of Medical Department, NAVMED P-117.

8. U.S. Navy Diving Manual, NAVSEA 0994-LP-001-9010.

9. Van Cott, H.P. and Kinkade, R.G. (Eds.) Human Engineering Guide to Equipment Design. Washington, D.C. American Institutes for Research, 1972.

APPENDIX A

MRT READING WORD LIST SAMPLE

	A	B	C	D	E		A	B	C	D	E
1.	bat	batch	bash	bass	badge	26.	led	shed	red	wed	fed
2.	laws	long	log	lodge	lob	27.	sold	cold	hold	told	gold
3.	wig	with	wit	witch	wick	28.	dig	wig	big	rig	pig
4.	dumb	dub	doth	duff	dove	29.	kick	chick	thick	pick	sick
5.	cuff	cub	cut	cup	cud	30.	fin	tin	shin	kin	thin
6.	dig	din	dic	dim	dill	31.	bark	dark	mark	lark	park
7.	dun	dud	dung	dub	dug	32.	gale	pale	tale	bale	male
8.	fill	fig	fin	fizz	fib	33.	peel	feel	eel	heel	keel
9.	leave	liege	leach	leash	lead	34.	will	hill	kill	till	bill
10.	toss	taj	tong	talks	tog	35.	feel	reel	seal	zeal	veal
11.	lash	lack	lass	laugh	lath	36.	shame	game	came	same	tame
12.	mat	mad	math	man	mass	37.	ten	pen	den	hen	then
13.	beige	base	bayed	bathe	bays	38.	pin	sin	tin	win	fin
14.	pass	path	pack	pad	pat	39.	thin	tin	chin	shin	gin
15.	peak	peas	peal	peace	peat	40.	thee	dee	lee	knee	zee
16.	pick	pit	pip	pig	pitch	41.	rent	bent	went	dent	tent
17.	pup	puff	pub	puck	pus	42.	hip	rip	tip	dip	lip
18.	hath	hash	half	have	has	43.	top	hop	pop	cop	shop
19.	we're	weal	weave	weed	wean	44.	yore	gore	wore	lore	roar
20.	sad	sat	sag	sack	sap	45.	vie	thy	fie	thigh	high
21.	sheen	sheave	sheathe	sheath	sheaf	46.	zip	lip	nip	gyp	slip
22.	sing	sip	sin	sit	sick	47.	nest	best	vest	rest	west
23.	sud	sum	sub	sun	sung	48.	bust	just	rust	gust	dust
24.	tab	tan	tam	tang	tap	49.	mat	vat	that	fat	rat
25.	teethe	tear	tease	teel	teeth	50.	way	may	gay	they	nay

APPENDIX A

MRT RESPONSE WORD LIST SAMPLE

NAME:______________________ RIG OR LOCATION:______________ DATE:______________

	A	B	C	D	E		A	B	C	D	E
1.	batch	bash	bass	bat	badge	26.	wed	shed	led	red	fed
2.	long	laws	lob	lodge	log	27.	told	hold	gold	cold	sold
3.	wig	with	witch	wit	wick	28.	dig	wig	rig	pig	big
4.	dumb	dub	duff	dove	doth	29.	thick	chick	kick	sick	pick
5.	cud	cup	cuff	cut	cub	30.	fin	tin	kin	thin	shin
6.	din	dim	dill	dig	did	31.	lark	dark	park	mark	bark
7.	dug	dun	dung	dub	dud	32.	pale	gale	tale	male	bale
8.	fin	fig	fib	fizz	fill	33.	heel	keel	feel	peel	eel
9.	leash	lead	leave	leach	liege	34.	till	hill	bill	kill	will
10.	taj	tog	tong	toss	talks	35.	veal	reel	zeal	feel	seal
11.	lass	laugh	lash	lath	lack	36.	came	same	shame	tame	game
12.	mad	mat	math	man	mass	37.	then	pen	den	hen	ten
13.	beige	base	bays	bathe	bayed	38.	win	fin	pin	tin	sin
14.	pack	pass	path	pad	pat	39.	shin	gin	thin	tin	chin
15.	peace	peat	peak	peas	peal	40.	thee	zee	knee	lee	dee
16.	pip	pig	pitch	pit	pick	41.	dent	went	tent	rent	bent
17.	puff	puck	pus	pup	pub	42.	dip	rip	tip	hip	lip
18.	half	hash	has	hath	have	43.	hop	pop	shop	top	cop
19.	weave	we're	wean	weed	weal	44.	gore	roar	yore	wore	lore
20.	sag	sack	sap	sad	sat	45.	thigh	high	vie	fie	thy
21.	sheave	sheen	sheath	sheaf	sheathe	46.	gyp	nip	zip	lip	slip
22.	sin	sip	sing	sit	sick	47.	nest	vest	west	rest	best
23.	sum	sun	sud	sub	sung	48.	bust	dust	rust	just	gust
24.	tab	tam	tap	tan	tang	49.	vat	fat	that	rat	mat
25.	teethe	teel	teeth	tear	tease	50.	they	gay	way	may	nay

APPENDIX B

HUMAN FACTORS
Chamber Communicator Evaluation
Test Number 83-28

Communicator Evaluated (circle): AMCOM II (2820) EFCOM DAR 1000 Industrial Intercom AD 27HM2

Helle 3214 Helle 3220

Date:________________________

Name:________________________

Operator #:____________________

Dominant Hand (circle): R L

Height:_______

A. Circle the most appropriate answer and make additional comments where necessary.

1. Do your fingers ever slip off any of the controls? YES_____ NO_____

   Comment:____

2. Do the controls on the communicator give a positive indication of activation (i.e. snap feel, audible click)? YES_____ NO_____

   Comment:____

3. Do the communicator labels clearly and correctly describe the equipment? YES_____ NO_____

   Comment:____

4. Are the labels of the communicator located on or near the items which they identify, so as to eliminate confusion with other items or labels? YES_____ NO_____

   Comment:____

5. Did you ever reach for, or operate, the wrong switch or knob? YES___ NO___

Comment:____

____

B. Answer the following questions by inserting the number corresponding to the appropriate rating next to the question.

Key:	1	2	3	4	5
	poor	below average	satisfactory	above average	excellent

6. Rate the ease of operation of controls on the communicator:__________

Comment:____

____

7. Rate the location of controls on the communicator:__________

Comment:____

____

8. Rate the clarity of sound received through the communicator from inside the chamber:__________

Comment:____

____

9. Rate the construction (i.e. materials, craftsmanship) of the communicator:________

Comment:____

____

10. Rate the aesthetics (beauty) of the communicator:________

Comment:____

____

____

C. Comment on how you would improve this communicator:____________________

Do you have confidence in the performance of this equipment? YES___ NO___

D. Remarks on any item of importance to you that was not covered by this questionnaire:

END

FILMED

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